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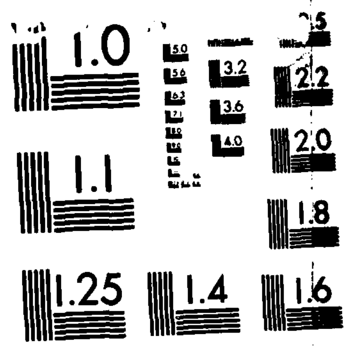

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Final Technical Report

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CONTENTS

2.1 ULTRA-LOW-FREQUENCY WAVES

2.1.1 Pc 3 Magnetic Pulsations

Magnetic pulsations classified as Pc 3 (15-45 s period) are a common phenomenon observed on the day side of the earth and also at synchronous orbit. They are well correlated with the solar wind and exhibit properties suggesting they are oscillations of magnetic field lines. Our previous studies of these pulsations, using data from the synchronous spacecraft ATS 6, have shown they consist of a number of harmonics. The frequency separation of adjacent harmonics depends on the distribution of plasma along the field line passing through the spacecraft. This makes it possible to determine the total mass density produced by particles of all energies and masses. Currently no other technique is available to make such a measurement.

During the past year we have continued to study the properties of Pc 3 pulsations observed at synchronous orbit. In one recently submitted paper (B-53),[1] we used multiple synchronous spacecraft to contrast the properties of Pc 3 observed simultaneously at several different locations. This work shows conclusively that the observed wave frequencies are a function of the

[1] In this progress report we reference our previous work by citations of the form (Appendix-Entry number).

local plasma mass density. As a consequence, spacecraft at different azimuthal or radial locations observe different frequencies. In rare situations, two spacecraft may be located on field lines with the same mass distribution and observe the same frequencies. Data from such events indicate the Pc 3 waves propagate azimuthally away from noon with a velocity of order 1700 km/s. This is much faster than expected for waves produced by the Kelvin-Helmholtz instability, suggesting instead that the waves are propagating internally rather than as surface waves on the boundary. We conclude that magnetosheath turbulence penetrating the magnetopause near local noon is the most likely mechanism for exciting the oscillating field lines.

We have also investigated the dependence of the Pc 3 spectrum at synchronous orbit on the interplanetary magnetic field. In a paper presented at the Chapman Conference on Waves in Magnetospheric Plasmas (A-75), and also in a paper submitted for publication (B-54), we found the amplitude of the higher harmonics of Pc 3 depends on the strength of the interplanetary magnetic field magnitude, but not on its direction. We compared the observed fundamental frequency at synchronous orbit to the expected frequency of waves observed upstream of the bow shock and found no relation. This led us to conclude that Pc 3 pulsations are not excited by upstream waves swept downstream into the magnetosheath.

In our earlier work on Pc 3 pulsations, we reported the existence of a class of radially polarized waves. Examination of dynamic spectra produced by our new techniques (B-52) did not show any such pulsations. To confirm this, we scanned the entire year of dynamic spectra and found no examples of radially polarized harmonic Pc 3 pulsations. In a paper submitted for publication (B-55), we demonstrate that the previous report was erroneous and a consequence of spacecraft noise preferentially along the radial axis of the magnetometer. There are, however, frequent occurrences of radially polarized second-harmonic pulsations. This class of waves never exhibits harmonic structure and occurs only when harmonic Pc 3 pulsations are absent.

While the exact source of Pc 3 wave energy is not known, a variety of results suggests that magnetosheath turbulence is responsible. During the last year we have examined this possibility, using data from magnetometers on two spacecraft straddling the magnetopause. Results were presented in a paper at the Chapman Conference on Waves in Magnetospheric Plasmas (A-77) and in a recently published manuscript (B-56). We find that power levels just inside the magnetopause are correlated with those outside, but 10 to 1000 times smaller. Also, the frequency spectra on the two sides of the boundary exhibit similar enhancements, often peaking in the Pc 3 band. Furthermore, the frequency of this enhancement appears to be related to the orientation of the interplanetary magnetic field.

The discovery of harmonic Pc 3 pulsations in space has stimulated a reexamination of ground data for similar effects. In a paper just submitted for publication (B-57), we have compared dynamic spectra of ground data with spectra at ATS-6. Typically, we find that ground spectra exhibit two bands of excitation, one centered on the fundamental and one centered on higher harmonics. Distinct bands corresponding to specific

higher harmonics usually cannot be resolved. Often, the two bands are not excited simultaneously, suggesting that their sources of excitation are different.

An invited review of our work on Pc 3 pulsations was presented at the IUGG meeting in Germany (A-89), and has been submitted for publication (B-66). The review concludes that Pc 3 pulsations are generated when magnetosheath turbulence is transmitted through the magnetopause near noon stimulating local field line resonances throughout the dayside magnetosphere.

2.1.2 Pc 1 Magnetic Pulsations

Pc 1 magnetic pulsations (.1 to 5 Hz) are often observed in the afternoon hours at synchronous orbit. These waves are known to be generated by the ion cyclotron instability of energetic protons in the ring current. Recent work has revealed that the spectral properties of these waves are significantly altered by the presence of heavy ions of helium and oxygen. Gaps in the spectrum and changes in the sense of polarization as a function of frequency are observable quantities that are related to the relative concentration of the heavy ions. Indirect measurements of these concentrations by Pc 1 observations provide more accurate determinations than is possible with existing particle detectors.

As the first step in our studies of Pc 1 magnetic pulsations, we have initiated a project to calculate dynamic spectra for all events observed by the ATS 6 spacecraft. Intervals during which a Pc 1 wave index indicates activity have been divided into two-hour segments and dynamic spectra prepared for each segment. Each dynamic spectrum has been examined and the type of Pc 1 activity classified. Preliminary results of this survey were presented at the Chapman Conference on Waves in Magnetospheric Plasmas (A-75). We find at least two distinct types of activity, one characterized by frequencies above the helium gyrofrequency and linear polarization, and another by frequencies below the helium gyrofrequency and left ellpitical polarization. Occasionally, a broad band emission spans the entire frequency band, exhibiting gaps at the helium gyrofrequency and switches in polarization at a crossover frequency. These broad-band emissions provide the data needed to deduce concentrations of heavy ions. The two main types occur at distinctly different local times, high frequency between 1000 and 1500, and low between 1500 and 1800. Both types are closely associated with the onset of substorm expansions.

2.2 PREDICTING GEOMAGNETIC ACTIVITY USING SOLAR WIND DATA

Over the past decade it has been established that the solar wind controls geomagnetic activity. Whether this control is completely deterministic or whether it contains a random component has not been decided. We have investigated this question using the technique of linear prediction filtering. In this technique, time histories of the input and output of a system are used to calculate an empirical impulse-response function. This function may then be used to predict the system output. A subtraction of the predicted and observed output reveals those components of the output which are uncorrelated with the input. During the last year we have applied this analysis technique to three common measures of geomagnetic activity: AL, ASYM, Dst. Respectively, these measure the strength of the westward electrojet, the strength of the partial ring current, and the strength of the symmetric ring current.

2.2.1 Auroral Electrojets

In work reviewed last year, we showed that the solar wind electric field is a better predictor of AL than the solar wind Poynting vector (epsilon). We have continued our study of the relationship of solar wind electric field to AL using a larger data set. In a paper presented at the Fall 1982 AGU meeting (A-74), we demonstrated that the average impulse response for this relation is a Raleigh function peaking at 40 minutes and decaying to zero after 2 hours. This corresponds to a low pass filter which attenuates all frequencies greater than 10**-4 Hz. This function predicts only the low-frequency component of the AL index. Sudden variations in this index caused by the onset of an expansion phase are not well predicted by the solar wind, suggesting they are caused by internal magnetospheric processes.

In another study reported at the Fall AGU meeting (A-72), and more recently at the IAGA meeting (A-92), we examined the dependence of the AL predictor on the level of geomagnetic activity. In disagreement with the assumption of a linear system, we find the predictor changes systematically with activity. At moderate levels of activity, the predictor has two comparable peaks, one at 20 minutes and one at 60 minutes. At high levels of activity, the magnitude of the first peak increases relative to the second, dominating the system characteristics. We have tentatively interpreted the first peak as representing effects of currents driven directly by the solar wind and the second peak as currents driven by release of energy from the magnetotail. A manuscript describing this work has been submitted to the J. Geophys. Res. (B-58), and is currently under revision.

2.2.2 Partial Ring Current

The partial ring current is a hypothetical current system invented to explain a large depression in the H component of midlatitude magnetograms centered at dusk. The strength of this depression is measured by the asymmetry index (ASYM). We have investigated the relation of this index to the solar wind electric field and reported results in a recently published paper (B-48). Using linear prediction filters, we find that the ASYM predictor is very similar to the AL predictor, indicating it is caused by similar processes. Our interpretation suggests that the perturbations monitored by ASYM are created by the field-aligned portion of currents which flow into the ionosphere near noon, westward through the electrojet, and outward just before midnight. The AL index, on the other hand, monitors the ionospheric portion of this current system.

2.2.3 The Symmetric Ring Current

In preliminary work carried out for a paper presented at the Chapman Conference on Magnetospheric Currents (A-78) we determined a prediction filter relating the solar wind electric field to the Dst index. We found this filter has an initial shape very similar to the AL and ASYM filters, but it has a long, slowly decaying tail. We interpret this filter as the superposition of two distinct physical processes, ring current injection and ring current decay. Injection is via a mechanism closely related to the substorm processes responsible for AL, while decay is a consequence of the slow process of charge exchange.

To better understand the nature of the injection process, we are attempting to remove the effects of decay and obtain a filter representing only the injection. A preliminary result suggests the injection process alone is represented by a Gaussian filter peaked at 20 minutes. Further work is required to examine details of this filter.

2.2.4 The Role of Driven and Unloading Processes in Substorms

For some time there has been a continuing controversy concerning the physical process responsible for substorms. In a paper submited for publication (B-50), we examined the roles of two important processes, currents directly driven by the solar wind, and release of energy stored in the geomagnetic tail. We conclude both processes are important, but their relative contribution varies from substorm to substorm. Typically, however, the driven process provides a background of activity, the "convection bay" upon which the storage/release process superposes its effect, the "substorm electrojet." Both processes are correlated with the solar wind, although the driven process appears to be more predictable.

2.3 A STUDY OF THE NEAR-EARTH PLASMA SHEET

For several years we have been involved in an ongoing study of the role of the near-earth plasma sheet in substorms. This study is being carried out as part of the Coordinated Data Analysis Workshop (CDAW-6) sponsored by the National Space Science Data Center. The workshop has carried out a detailed study of an isolated substorm which occurred at the equinox just as the pair of spacecraft, ISEE-1 and -2, passed through the midnight sector of the near-earth plasma sheet. During 1983 two special symposia were held to present results of this workshop: one at the Spring meeting of the AGU, and one at the XVIII meeting of the IUGG in Hamburg. Currently, manuscripts describing the results are in preparation.

An overview of the CDAW-6 substorm was presented at both conferences by the principal investigator (A-79, A-85) and has been circulated as a draft manuscript (B-64) to all participants. This overview establishes the time line for the event and demonstrates the data are consistent with the view that a neutral line formed close to the earth during the expansion phase. A more detailed description of the changes in the tail magnetic field was also presented by the principal investigator (A-80, A-86). These changes demonstrate that the strongly southward field observed in the plasma sheet immediately after the substorm expansion onset was not an artifact of neutral sheet orientation. The field changes were also used to obtain rough estimates of the thickness and motion of the plasma sheet during different phases of the substorm.

Another aspect of the CDAW-6 study in which we have participated is an examination of the ionospheric currents flowing during different phases of the substorm. Using ground magnetometer records and an ionospheric conductivity model, we show (A-82) that two major current systems take part in a substorm. The first is the convection electrojet system made up of a global system of eastward and westward electrojets driven directly by the solar wind. The second is a substorm electrojet consisting of an addition to the westward electrojet in the midnight sector, driven by a diversion of the tail current during the expansion phase.

A final aspect of the CDAW-6 study to which we have contributed is a search for evidence of energy storage in the magnetotail during substorms. Using results of the ionospheric current modeling described above, we show (A-81) that the global Joule heating rate during the expansion phase is two to three times as great as that during solar wind driven convection. Furthermore, we demonstrate that the expansion phase is characterized by an interval during which the tail lobe magnetic energy density decreases as, simultaneously, the field at synchronous orbit becomes less taillike. We conclude that overall the effects of energy release from the tail are comparable to the effects of solar wind convection as far as Joule heating is concerned.

2.4 METHODS OF TIME SERIES DATA BASE MANAGEMENT

In the absence of commercial developments of software for managing time series data, we have continued to develop our own methods. Several years ago we defined a general data format for time series data which we called the "flat file." The flat file consists of two files, a header file and a data file linked by a naming convention. The header file is a sequential ASCII file containing documentation characterizing the data file and its attributes. The data file is a random-access binary file that contains data in the form of a sequence of fixed-length records. Each record contains one row of a table, i.e. of a "flat file."

During the last year we continued develpment of application programs using flat files. A major accomplishment during this time was a set of three programs for editing flat files, automatically producing gapless, despiked and flag-free data for use by other processors. Also, we have completed an interactive program to implement the IEEE filtering programs using flat files as input and output. We have also made progress in the preparation of documentation describing the flat file system. A general overview has been prepared (B-65), and a presentation made describing potential applications of this system to geophysical exploration (A-94). In addition, two oral presentations chracterizing the system were given at the IUGG interdisciplinary symposium on Geophysical Data Management held at the recent meeting in Hamburg (A-83 and A-84).

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